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(54) **MICROPHONE SYSTEM WITH A STOP MEMBER**

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CPC ***H04R 19/04*** (2013.01); ***H04R 19/005*** (2013.01)

(58) **Field of Classification Search**
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See application file for complete search history.

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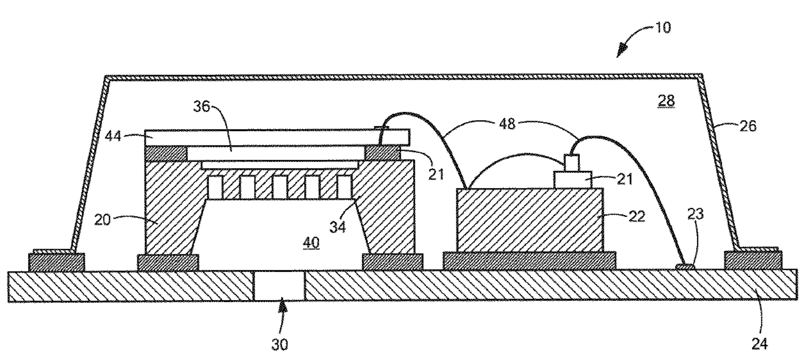
(57) **ABSTRACT**

A microphone system has a package with an interior chamber and an inlet aperture for receiving an acoustic signal, and a microphone die having a backplate and a diaphragm. The microphone is positioned within the package interior to form a front volume between the diaphragm and the inlet aperture. Accordingly, the microphone is positioned to form a back volume defined in part by the diaphragm within the interior chamber. The system also has a stop member positioned in the back volume so that the diaphragm is between the stop member and the backplate.

21 Claims, 8 Drawing Sheets



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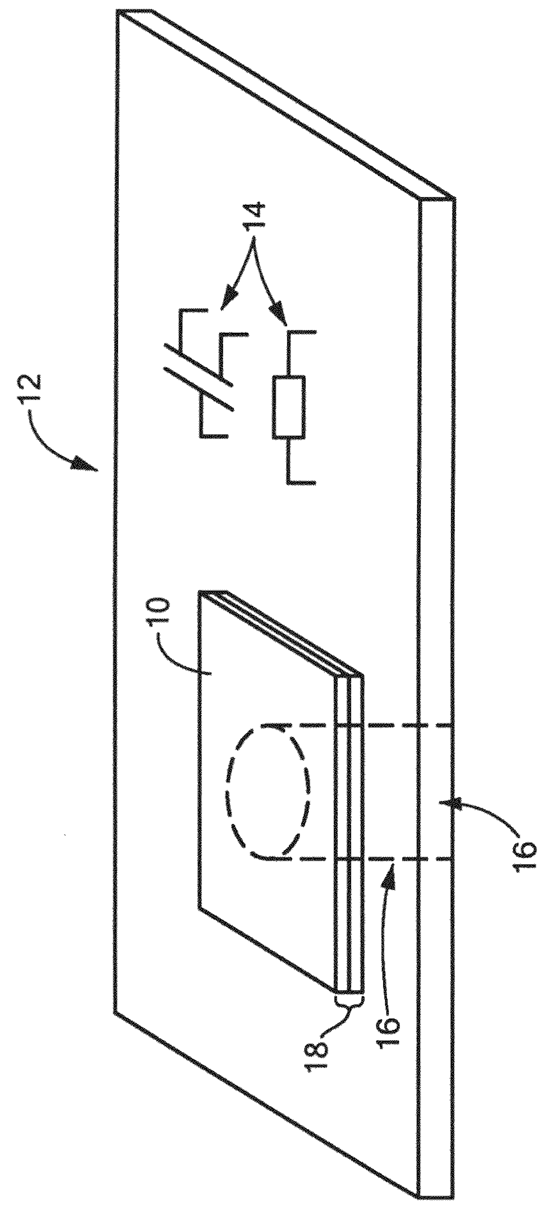

FIG. 1

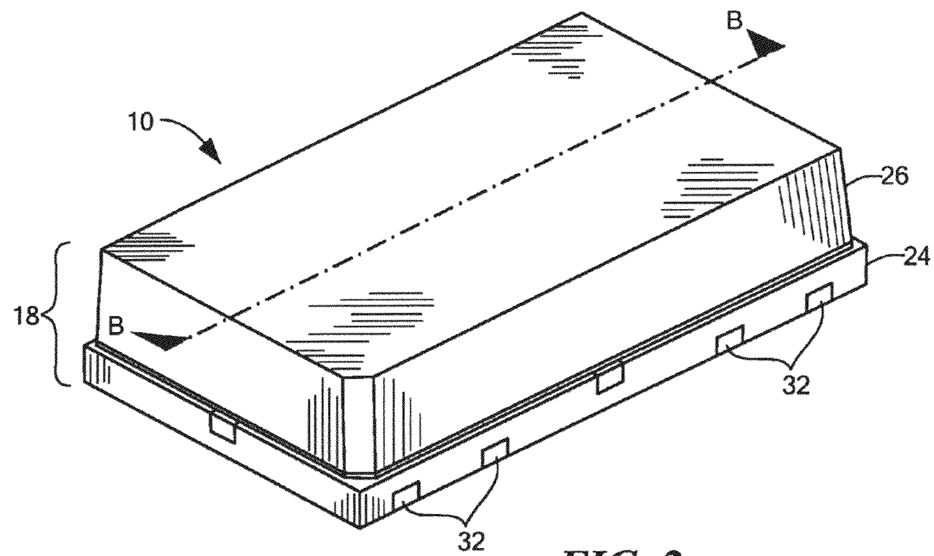

FIG. 2

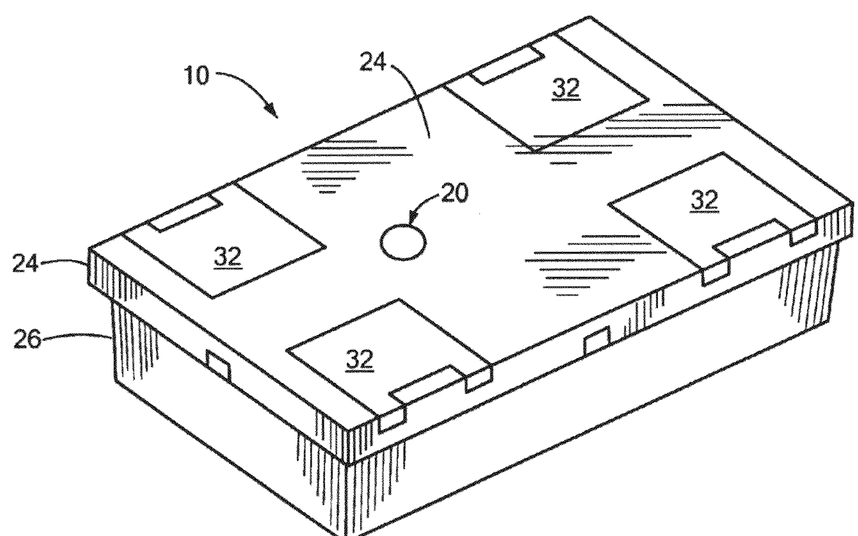

FIG. 3

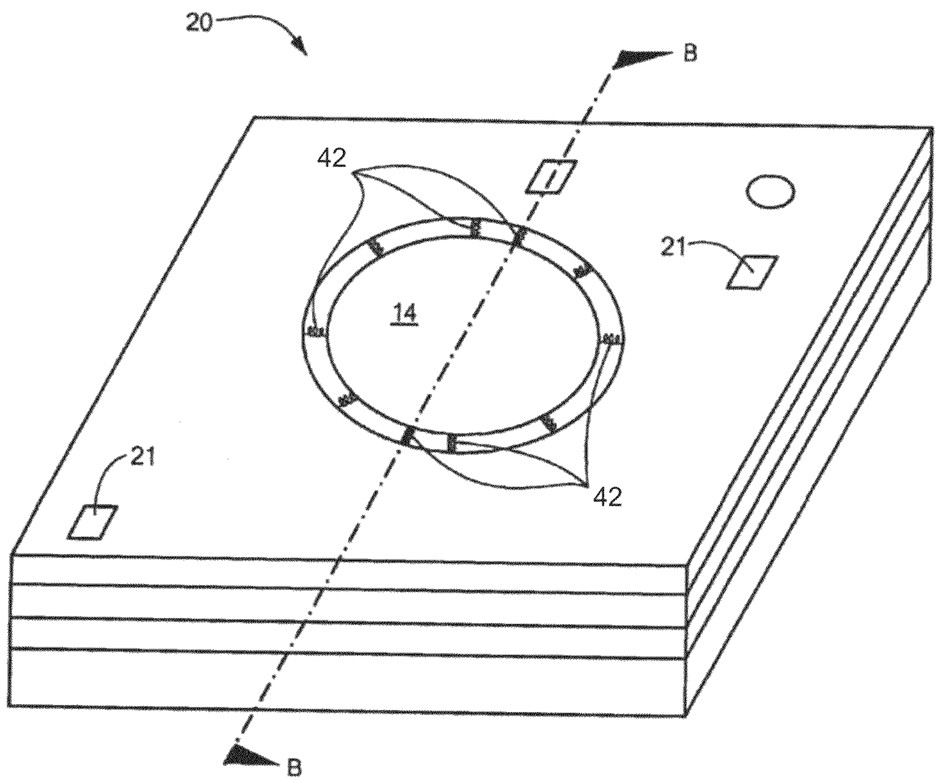

FIG. 4

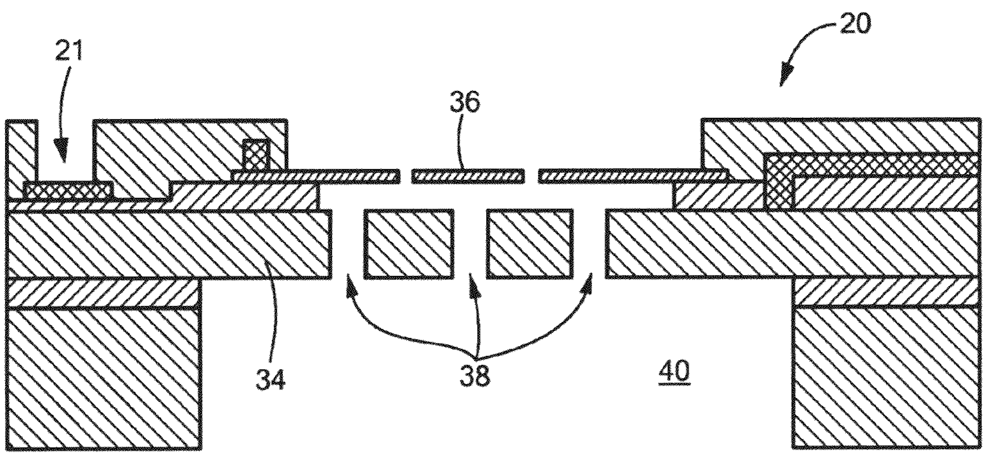

FIG. 5

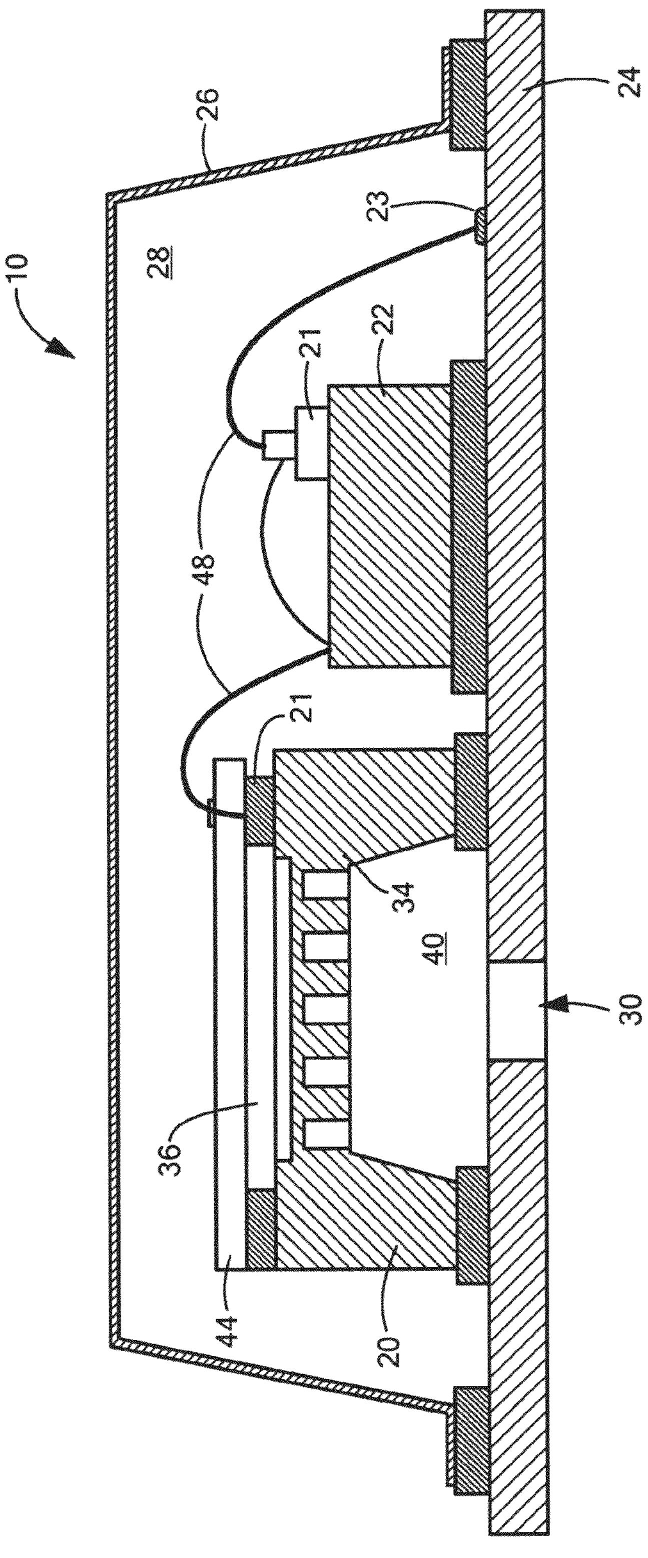

FIG. 6A

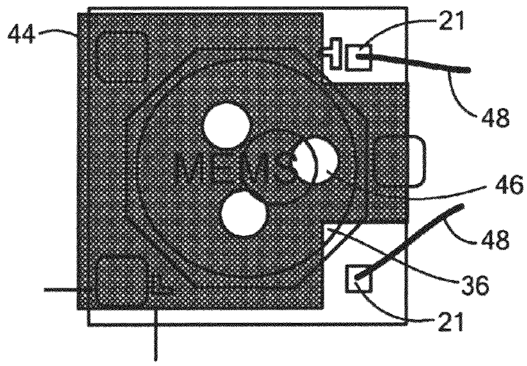

FIG. 6B

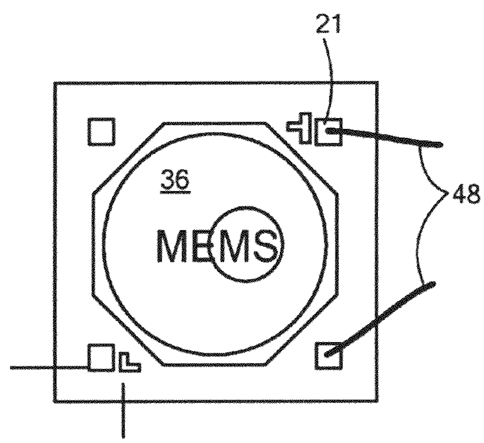

FIG. 6C

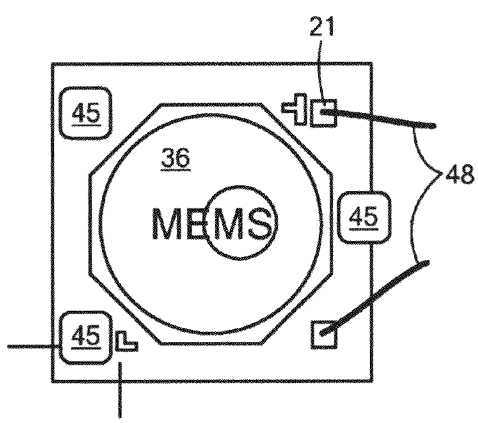

FIG. 6D

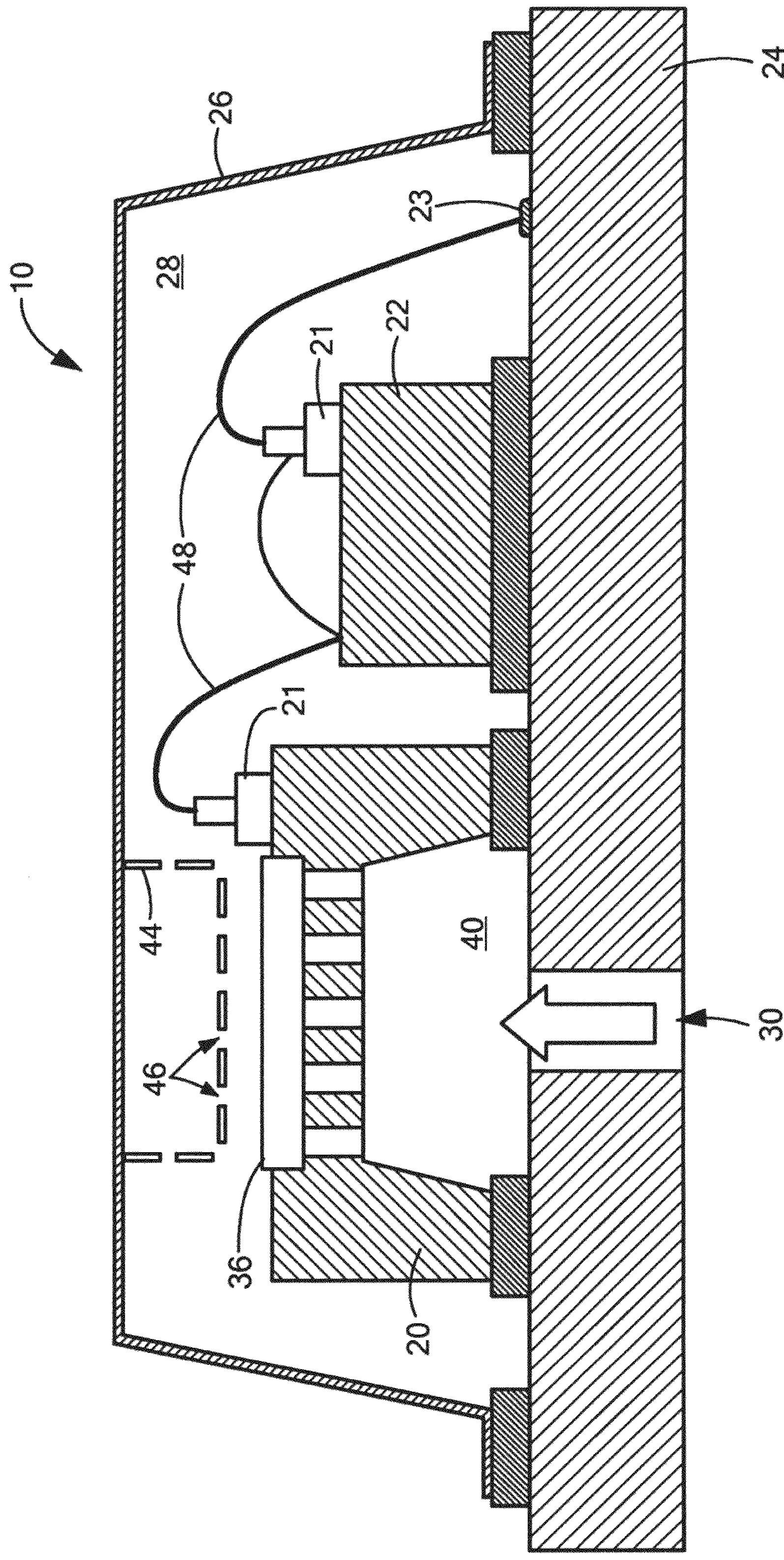

FIG. 7

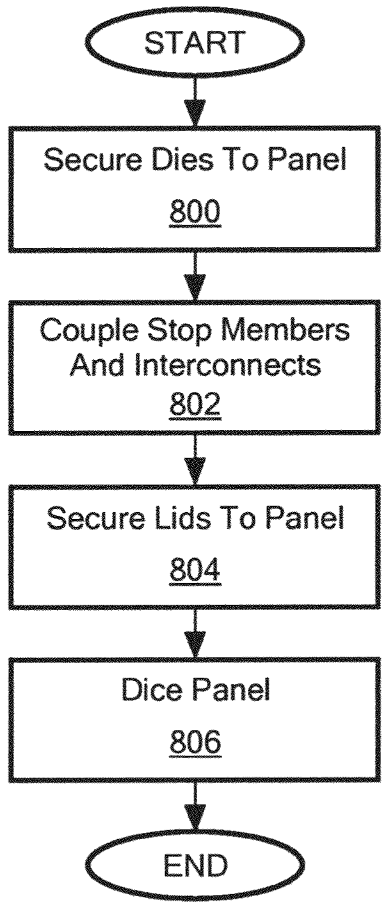
START
Secure Dies To Panel
800
Couple Stop Members
And Interconnects
802
Secure Lids To Panel
804
Dice Panel
806
END

FIG. 8

MICROPHONE SYSTEM WITH A STOP MEMBER

FIELD OF THE INVENTION

The invention generally relates to microphone systems and, more particularly, the invention relates to transducers.

BACKGROUND OF THE INVENTION

MEMS microphones (i.e., microelectromechanical system microphones) typically are secured within the interior chamber of a package to protect them from the exterior environment. An integrated circuit chip, typically mounted within the interior chamber and having active circuit elements, processes electrical signals to and from the microphone. One or more apertures through some portion of the package permit acoustic signals to reach the microphone. Receipt of the acoustic signal causes the microphone, with its corresponding integrated circuit chip, to produce an electronic signal representing the acoustic qualities of the received signal.

Since they are exposed to the exterior environment through their apertures(s), MEMS microphones often are subject to high pressure events that can damage their fragile microstructure.

SUMMARY OF VARIOUS EMBODIMENTS

In accordance with one embodiment of the invention, a microphone system has a package with an interior chamber and an inlet aperture for receiving an acoustic signal, and a single backplate microphone die having a backplate and a diaphragm. The microphone is positioned within the package interior to form a front volume between the diaphragm and the inlet aperture. Accordingly, the microphone is positioned to form a back volume defined in part by the diaphragm within the interior chamber. The system also has a stop member positioned in the back volume so that the diaphragm is between the stop member and the backplate.

The stop member may be spaced a given distance (e.g., between about 5 and about 16 microns) from the generally planar top surface of the diaphragm to limit orthogonal movement of the diaphragm in a direction that is generally normal to the top surface of the diaphragm. The maximum orthogonal movement is about the same as the given distance. That distance may be greater than the distance between the diaphragm and the backplate. Moreover, the stop member may have a floating potential, or a potential that is substantially the same as the potential of the diaphragm.

Some embodiments secure the stop member to the microphone die. For example, the stop member and microphone die may be secured together in a stacked configuration. Other embodiments couple the stop member to at least one interior wall that defines the interior chamber.

To facilitate diaphragm movement, the stop member may be formed as a generally planar member (e.g., a laminate) having at least one opening therethrough. To form the front volume and back volume in the requisite manner, the microphone die may be positioned to substantially cover the inlet aperture.

The package may include a base forming the inlet aperture, and a lid secured to the base. The lid and base also may form the interior chamber and have a plurality of pads on the base (e.g., in the interior chamber, on the exterior package surface, or both surfaces).

In accordance with another embodiment of the invention, a microphone system has a lid that, at least with a base, forms

a package having an interior chamber and an inlet aperture for receiving an acoustic signal. The system also has a single backplate microphone die within the interior chamber, and a stop member proximate to the microphone die. The microphone die is mounted over and covers the inlet aperture, and is positioned between the inlet aperture and the stop member.

In accordance with other embodiments of the invention, a microphone system has a lid that, at least with a base, forms a package having an interior chamber and an inlet aperture for receiving an acoustic signal. The system also has a single plate microphone die within the interior chamber—mounted over and covering the inlet aperture. The microphone die has a diaphragm suspended by at least one spring, and a backplate that forms a variable capacitor with the diaphragm. The spring permits the diaphragm to move a maximum distance in a direction that is generally orthogonal to the top generally planar face of the diaphragm. The maximum distance is a distance that would damage the microphone die. Accordingly, the system also has a stop member positioned proximate to and spaced a given distance from the diaphragm in a direction that is generally orthogonal to the top face of the diaphragm. The given distance is less than the maximum dimension. The stop member is positioned between the diaphragm and the lid to prevent the diaphragm from moving more than the given distance in the direction of the lid.

BRIEF DESCRIPTION OF THE DRAWINGS

Those skilled in the art should more fully appreciate advantages of various embodiments of the invention from the following "Description of Illustrative Embodiments," discussed with reference to the drawings summarized immediately below.

FIG. **1** schematically shows one use of a packaged microphone system configured in accordance with illustrative embodiments of the invention.

FIG. **2** schematically shows a top view of a packaged microphone that may be configured in accordance with illustrative embodiments of the invention.

FIG. **3** schematically shows a bottom view of the packaged microphone shown in FIG. **2**.

FIG. **4** schematically shows a perspective view of a microphone die that may be used in accordance with illustrative embodiments of the invention.

FIG. **5** schematically shows a cross-sectional view of the microphone die shown in FIG. **4**.

FIG. **6**A schematically shows a cross-sectional view of the packaged microphone of FIGS. **2** and **3** in accordance with illustrative embodiments of the invention.

FIGS. **6**B-**6**D schematically show top views of the packaged microphone of FIGS. **2** and **3** with the lid removed during various stages of the packaging process.

FIG. **7** schematically shows a cross-sectional view of the packaged microphone of FIGS. **2** and **3** in accordance with an alternative embodiment of the invention.

FIG. **8** shows a process of producing the packaged microphone accordance with illustrative embodiments of the invention.

DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

In illustrative embodiments, a MEMS microphone is configured to maintain its structural integrity when subjected to sudden high pressure acoustic signals. To that end, the MEMS microphone has a stop member that limits the distance its flexible diaphragm may travel away from its local backplate.

Specifically, the stop member ensures that the diaphragm cannot move a distance that could potentially damage the diaphragm and/or its springs (among other things). Details of illustrative embodiments are discussed below.

FIG. **1** schematically shows one application of a microphone system that can implement illustrative embodiments of the invention. Specifically, FIG. **1** schematically shows a printed circuit board **12** supporting and electrically interconnecting a packaged microphone **10** with additional electronic components **14**. The packaged microphone **10** cooperates with on-board and off-board circuitry to convert and deliver audio/acoustic signals to a larger system, such as a mobile telephone or public announcement system.

A board aperture **16** (shown in phantom) extends upwardly through the printed circuit board **12** to the bottom of the microphone package (identified by reference number **18**, discussed in detail below). To ensure proper receipt of the acoustic signal, the microphone package **18** may be sealed to the top surface of the printed circuit board **12** by means of a gasket (e.g., formed from an elastomeric or other sealing material, not shown) or without a gasket, such as with some foam or elastomeric material. Accordingly, this arrangement produces an acoustic signal path through the printed circuit board **12**, the gasket, and an inlet aperture **30** in the bottom surface of the package **18**.

Those skilled in the art can mount the packaged microphone **10** onto the printed circuit board **12** using any of a variety of different techniques. For example, surface mount technology or lead-through-board technologies (e.g., gull wing mounting) should suffice. Moreover, it should be noted that only the packaged microphone **10** and two other miscellaneous circuit components **14** are shown for simplicity. The circuit board **12** thus may have a number of other components, such as additional microphones, resistors, capacitors, transistors, application-specific integrated circuits, traces, contact pads, etc. . . .

Indeed, the packaged microphone **10** of this embodiment has a microphone package **18** that contains both a MEMS microphone (hereinafter "microphone die **20**") and application-specific internal circuit ("ASIC **22**" or "circuit die **22**"). Illustrative embodiments may use a variety of different types of MEMS microphone dies, such as that shown in cross-section by example in FIGS. **4** and **5**.

To those ends, FIG. **2** schematically shows a top, perspective view of a packaged microphone **10** (also referred to as a "packaged microchip **10**" or "microphone system **10**") that may be configured in accordance with illustrative embodiments of the invention. In a corresponding manner, FIG. **3** schematically shows a bottom, perspective view of the same packaged microphone **10**.

The packaged microphone **10** shown in those figures has a package base **24** that, together with a corresponding lid **26**, forms an interior chamber **28** (shown in FIGS. 6A and **7**) containing the noted microphone die **20** and, if desired, the noted separate circuit die **22**. Alternatively, the microphone die **20** has on-chip circuitry, thus obviating the need for separate microphone circuitry within the chamber **28**. The lid **26** in this embodiment is a cavity-type lid, which has four walls extending generally orthogonally from a top, interior face to form a cavity. The lid **26** secures to the top face of the substantially flat package base **24** to form the interior chamber **28**. In alternative embodiments, the lid **26** and base **24** combine with other components (e.g., an intervening wall between the lid **26** and the base **24**) to form the interior chamber **28**. Other embodiments may implement the base **24** as a cavity package (with a bottom and walls extending from a flat surface), and/or the lid **26** in a generally flat planar shape.

As shown in FIG. **3**, the base **24** has an audio/acoustic input port **30** (also referred to as an "input aperture **30**" or "inlet aperture **30**") that enables ingress of audio/acoustic signals into the interior chamber **28**. Acoustic signals entering the interior chamber **28** interact with the microphone die **20** to produce an electrical signal that, with additional (exterior) components (e.g., a speaker and accompanying on-chip or off-chip circuitry), produce an output audible signal corresponding to the input audible/acoustic signal.

In alternative embodiments, however, the inlet aperture **30** is at another location, such as through the top of the lid **26**, or through one of the side walls of the lid **26**. For example, the inlet aperture **30** can extend through the lid **26** with a connection to the microphone die **20**. The package **18** also may have two or more ports/apertures **30**. For example, the package **18** could have a second input port (not shown) for directional sound purposes. Accordingly, discussion of a package **18** having its inlet aperture **30** through the base **24** is but one example of a variety of different embodiments.

FIG. **3** also shows a number of base contacts **32** for electrically (and physically, in many anticipated uses) connecting the microphone die **20** with a substrate, such as the printed circuit board **12** of FIG. **1** or other electrical interconnect apparatus. For example, the base contacts **32** may be surface mountable pads or leads. The packaged microphone **10** may be used in any of a wide variety of applications. For example, the packaged microphone **10** may be used with mobile telephones, land-line telephones, computer devices, video games, biometric security systems, two-way radios, public announcement systems, camcorders, and other devices that transduce signals.

In illustrative embodiments, the package base **24** shown in FIGS. **2** and **3** is a premolded, leadframe-type package (also referred to as a "premolded package"). Other embodiments may use different package types, such as, among other types, ceramic cavity packages, substrate packages, or laminate base (e.g., BT) packages. Accordingly, discussion of a specific type of package base is for illustrative purposes only.

The package **18** may have selective metallization to protect it from electromagnetic interference. For example, the lid **26** could be formed from stainless steel, while the base **24** could include printed circuit board material, such as metal layers and FR-4 substrate material. Alternatively, the lid **26** could be formed from an insulator, such as plastic, with an interior conductive layer. Other embodiments contemplate other methods for forming an effective Faraday cage that reduces electromagnetic interference with the internal microphone die **20**. Moreover, various embodiments may form the base **24** and lid **26** from similar or the same materials. For example, both can be formed from a laminate, or the lid **26** can be formed from a laminate, while the base **24** can be formed from a carrier or pre-molded leadframe.

The interior chamber **28** can contain any of a variety of different types of microphone dies **20**. To that end, FIG. **4** schematically shows a perspective view of one type of microphone die **20** that may be used in illustrative embodiments. For more detail, FIG. **5** schematically shows a cross-sectional view of the microphone die **20** of FIG. **4**.

Among other things, the microphone die **20** includes a single static backplate **34** that supports and forms a variable capacitor with a flexible diaphragm **36**. In illustrative embodiments, the backplate **34** is formed from single crystal silicon (e.g., the top layer of a silicon-on-insulator wafer; a "SOI" wafer), while the diaphragm **36** is formed from deposited polysilicon. Other embodiments, however, use other types of materials to form the backplate **34** and the diaphragm **36**. For example, a single crystal silicon bulk wafer, or some deposited material may form the backplate **34**. In a similar manner, a single crystal silicon bulk wafer, part of a silicon-on-insulator wafer, or some other deposited material may form the diaphragm **36**. To facilitate operation, the backplate **34** has a plurality of through-holes **38** that lead to a backside cavity **40**. As discussed below, these through-holes **38** have a secondary function of acting as a filter that helps prevent debris from contacting the diaphragm **36**.

Springs **42** movably connect the diaphragm **36** to the static portion of the microphone die **20**, which includes the backplate **34**. Other embodiments have no springs. Audio/acoustic signals cause the diaphragm **36** to vibrate, thus producing a changing capacitance. On-chip or off-chip circuitry (e.g., the circuit die **22**, among other things) receive and convert this changing capacitance into electrical signals that can be further processed. For example, the diaphragm **36** may oscillate about an equilibrium position (i.e., the rest position for the diaphragm **36**) in a direction that is generally orthogonal to its top and bottom faces. Normally, this oscillation should be minimal. Undesirably, however, the springs **42** may permit a much greater diaphragm swing about the equilibrium position. This greater swing could be so large as to damage the diaphragm **36** and/or springs **42** (discussed below).

The microphone shown in FIGS. **4** and **5** often is referred to as a "single backplate microphone." Specifically, this type of microphone has only one backplate **34**; namely, the backplate **34** between the diaphragm **36** and the backside cavity **40**. Alternative embodiments (not shown in the figures) may divide the backplate **34** into a plurality of sub-backplates **34** that are in the same plane and/or on the same side of the diaphragm **36** and thus, they are still considered a single backplate **34**. Accordingly, some backplate embodiments may produce a single variable capacitance, while others produce a single variable capacitance from multiple variable sub-capacitances with one or more diaphragms **36**. Because they both use single backplates **34** to reproduce the incoming acoustic signal, both examples thus may be considered to effectively form a single plate variable capacitance. This is in contrast to a double backplate MEMS microphone design, which has backplates on both sides of the diaphragm **36**.

It should be noted that discussion of the specific microphone die **20** shown in FIGS. **4** and **5** is for illustrative purposes only. For example, as noted above, the microphone die **20** may have multiple sub-diaphragms **36** facing multiple-sub-backplates **34**, or be formed from a bulk silicon wafer and not from an SOI wafer. Other microphone configurations thus may be used with illustrative embodiments of the invention.

The positioning of the diaphragm **36** and backplate **34** presents a balance between having a sufficiently high variable capacitance signal and potential interference with free diaphragm movement. Specifically, while the diaphragm **36** typically is positioned very close to the backplate **34** to provide a strong variable capacitance signal, it preferably is spaced far enough away to not clip the signal by frequently contacting the backplate **34**. For example, a diaphragm **36** spaced about 3 to 4 microns away from the backplate **34** should provide sufficient clearance for normal operation of certain microphone dies **20**. In that case, that diaphragm **36** normally may vibrate up to about three microns about its equilibrium position (i.e., as noted above, the position of the diaphragm **36** when no acoustic signal is received).

Undesirably, however, the microphone die **20** may be subjected to sudden and sometimes short high pressure events (e.g., pressure spikes) that forcefully move the diaphragm **36** far away from the backplate **34**, beyond its normal range. For example, when used within a mobile telephone, a high-pressure event may occur when closing a car door, or positioning the device inside a sealed strong box that is suddenly closed. This can cause a shock or sudden pressure that can forcefully move the diaphragm **36** away from the backplate **34** a substantial distance, which can damage the fragile microstructure (e.g., the diaphragm **36** and springs **42**) and disable the microphone die **20**. For example, simulations of a specific microphone die **20** similar to that discussed above showed that such shocks can move the diaphragm **36** fifteen or more microns from the equilibrium point. Such simulations of that specific microphone die also demonstrated that displacements of greater than about seventeen microns could actually break the diaphragm **36**. In other words, although it does not always damage the diaphragm **36** and/or springs **42**, such a large displacement is expected to often damage the diaphragm **36** and/or springs **42**—it is outside of the rated range for the microphone die **20**.

The inventors responded to this problem by positioning a stop member **44** relatively close to the side of the diaphragm **36** that is opposite the backplate **34**. To mitigate the risk of damaging the microphone die **20**, the stop member **44** can be positioned a distance from the diaphragm **36** that is less than the maximum distance the diaphragm **36** can travel before being highly likely to break or damage the microstructure. For example, the stop member **44** can be placed between five and fifteen microns from the diaphragm **36** in its equilibrium position—preventing it from exceeding rated distances. Accordingly, the stop member **44** limits diaphragm movement to a distance that should not damage the microphone die components (e.g., the diaphragm **36** and/or the springs **42**).

To that end, FIG. **6**A schematically shows a cross-sectional view of the packaged microphone **10** of FIGS. **2** and **3** in accordance with illustrative embodiments of the invention. As noted above, the interior chamber **28** has the noted microphone die **20** for receiving incoming acoustic signals, and an ASIC die **22** electrically controlling the microphone die **20** (e.g., biasing its plates and managing signal transmission to and from the package **18**). The interior chamber **28** may have additional components that are not shown, such as passive components and integrated passive devices.

The microphone die **20** preferably is mounted directly over and covering the inlet aperture **30**. Accordingly, incoming acoustic signals enter the interior chamber **28** and pass through the backside cavity **40** and backplate **34** through-holes **38** before striking the diaphragm **36**. As known by those skilled in the art, this region between the inlet aperture **30** and the diaphragm **36** is known as the "front volume" of the microphone die **20**, or the front volume of the interior chamber **28**. Other embodiments, however, may position the microphone die **20** in other regions of the interior chamber **28**. Accordingly, discussion of this embodiment is for exemplary purposes only.

In accordance with illustrative embodiments of the invention, the packaged microphone **10** also has the above noted stop member **44** to protect the structural integrity of the microphone die **20**. To that end, the stop member **44** may be directly secured to the microphone die **20** in the back volume of the interior chamber **28**. In this embodiment, the stop member **44** is considered to be in a "stacked configuration" with the microphone die **20**. Specifically, in this stacked configuration, the stop member **44** is stacked upon the top, generally planar surface of the microphone die **20** within the interior chamber **28**. The stop member **44** thus has a generally planar bottom face (from the perspective of these drawings) that is generally parallel with the generally planar top face of the diaphragm **36**. Alternative embodiments of the stop member **44**, however, may be non-planar, with dimples, curved portions, or other similar features (discussed below).

The stop member **44** may be an integral part of the microphone die **20**—formed on the die **20** during the die fabrication/micromachining process. Alternatively, the stop member **44** may be formed as a separate component secured to the microphone die **20** in a post-fabrication processing step (discussed in greater detail below with regard to FIG. **8**). Among other things, the stop member **44** may be formed from a heterogeneous or homogeneous material, such as one or more of single crystal silicon, polysilicon, laminate (e.g., BT laminate), circuit board material (e.g., BT laminate or FR-4 circuit board material), metal, ceramic, or other material that may be used in semiconductor or packaging processes.

Illustrative embodiments ensure that the stop member **44** does not appreciably impede the intended movement of the diaphragm **36**. To that end, as noted above, the stop member **44** preferably is positioned relatively far from the diaphragm **36** in its equilibrium position. Among other ranges, this gap can range from slightly more the normal range of motion of the diaphragm **36** to multiple times that range. For example, the above discussed microphone having a diaphragm **36** that normally moves about three microns above and below its equilibrium point may position the stop member **44** between about four and about fifteen microns from the diaphragm **36** above the equilibrium position. As such, this embodiment should prevent the diaphragm **36** from moving a distance that could potentially damage the fragile microstructure of the microphone die **20**. Moreover, alternative embodiments space the stop member **44** a distance that is the same or closer to the diaphragm **36** than the spacing between the backplate **34** and the diaphragm **36**.

To further reduce its impact on normal microphone operation, the stop member **44** also may have one or more relief holes **46** or other similar features to relieve squeeze film damping effects it may produce. FIG. **6**B, for example, shows a top view of the stop member **44** and its plurality of pressure relief holes **46**. Moreover, this view also shows that the stop member **44** does not necessarily cover the entire surface area of the diaphragm **36**. Instead, the stop member **44** may have portions around its periphery that, from a plan view, do not cover the diaphragm **36**. In fact, some embodiments may implement the stop member **44** to have a very small surface area. For example, such embodiments may implement the stop member **44** as a mesh or other structure that, if necessary, merely provides point or line contact to the diaphragm **36**. To improve manufacturability, some embodiments may form a single large hole **46** through the stop member **44**. This single hole **46** may have a diameter that is slightly smaller than the diameter of the diaphragm **36** and, in some embodiments, is generally concentric with the diaphragm **36**. Accordingly, the stop member **44** contacts the outer periphery of the diaphragm **36** only during a high pressure event.

To ensure proper microphone performance, illustrative embodiments mitigate the electrostatic impact of the stop member **44** on the diaphragm **36**. For example, the stop member **44** may have a floating voltage, a negligible voltage (e.g., if it were formed from a non-conductive material), or have a controlled bias voltage, such as a voltage that is substantially equal to that of the diaphragm **36**. The stop member **44** nevertheless cannot be considered to be a backplate **34** and thus, does not form a variable capacitance that is used in any manner by the ASIC or packaged microphone **10**. Instead, the stop member **44** generally is a substantially inert, generally electrically irrelevant member with a principal function of limiting the maximum distance that the diaphragm **36** may move. As known by those skilled in the art, incidental electrostatic interaction with the diaphragm **36** does not transform it into a backplate **34**, especially where it does not perform such a function within the packaged microphone **10**.

FIGS. **6**C and **6**D schematically show additional plan views of the microphone die **20** before the stop member **44** is secured to its top surface. As noted above, details of this process are discussed below with regard to FIG. **8**.

Alternative embodiments do not form the stop member **44** directly on the microphone die **20**. FIG. **7** schematically shows one such embodiment, in which the stop member **44** extends downwardly (from the perspective of the drawings) from the interior surface of the lid **26**, but does not contact the microphone die **20** in any manner when the diaphragm **36** is in its equilibrium position. Like the embodiment described above with regard to FIG. **6**A, this embodiment also is configured to minimize its impact on diaphragm movement. As such, like the stop member **44** in FIG. **6**A, this stop member **44** also has features (e.g., apertures) that permit airflow through its body, and may be spaced far enough from the diaphragm **36** to reduce its damping effect on the diaphragm **36**. In addition, also like the stop member **44** discussed above with regard to FIG. **6**A, this stop member **44** also may have a minimum potential contact area with the diaphragm **36**, and minimal electrostatic interaction with the diaphragm **36** (e.g., the stop member **44** also does not form or perform the function of a backplate **34**).

Discussion of the specific stop member configurations of FIGS. **6**A and **7** are but two of a number of different potential implementations. Those skilled in the art therefore can configure the stop member **44** in any number of additional manners, such as a stop member **44** that is merely around at least a portion of the periphery of the diaphragm **36**, or only at certain locations (e.g., a collection of spaced apart components that effectively form a single stop member **44**).

FIG. **8** shows a process of forming the microphone system/packaged microphone **10** in accordance with illustrative embodiments of the invention. It should be noted that for simplicity, this described process is a significantly simplified version of an actual process used to form the microphone system **10**. Accordingly, those skilled in the art would understand that the process may have additional steps and details not explicitly shown in FIG. **8**. Moreover, some of the steps may be performed in a different order than that shown, or at substantially the same time. Those skilled in the art should be capable of modifying the process to suit their particular requirements.

In illustrative embodiments, the packaged microphone **10** is formed in a batch process that simultaneously forms dozens, hundreds, or even thousands of packaged microphones at the same time. To that end, this process is described as using panels of packaging material (e.g., laminate, FR-4, ceramic substrate material, or pre-molded leadframe packaging) that ultimately form the bases **24** of each of the packaged microphones **10**. It nevertheless should be noted that those skilled in the art can apply these techniques to other batch processes, or processes that form only one microphone at a time.

The process begins at step **800**, which secures the microphone die **20** and ASIC die **22** to the base **24**. More specifically, the panel is considered to have a two dimensional array of individual bases **24** that each ultimately form a portion of a single packaged microphone **10**. Each base **24** has its preformed inlet aperture **30** and configuration of contacts/pads **32** on its upper surface. Accordingly, the process first may apply adhesive to the panel at prescribed locations on the upper panel surface. This adhesive may be a conductive or non-conductive epoxy commonly used in the MEMS packaging space. Next, this step may place an array of microphone dies **20** in designated location over their respective inlet apertures **30**, and an array of ASICs in their designated locations next to the microphone dies **20**. The step also may position passive components or other devices onto prescribed portions of the panel. The cured adhesive effectively secures each of these components to the panel.

After the components are secured to the panel, the process continues to step **802**, which electrically connects the microphone dies **20** and ASICs **22** to their bases **24**, and couples the stop members **44** to the microphone dies **20**. Specifically, this step first applies a conductive adhesive to certain pads **21** on the top surfaces of the microphone dies **20** and the ASIC dies **22**. This step also applies the conductive adhesive to pads **23** on the top face of the panel. As shown in FIG. **6**C, this step next secures wire bonds **48** between the microphone dies **20** and their respective ASIC dies **22**, and between the ASIC dies **22** and those pads **23** on the top face of the panel with the adhesive. Alternatively, some embodiments may directly connect the microphone die **20** to the panel. In that case, the ASIC die **22** and microphone die **20** electrically communicate through electrical traces or conductive paths within the base **24**.

Next, as shown in FIG. **6**D, this step dispenses stop adhesive **45** onto the top surfaces of the array of microphone dies **20**. Those skilled in the art should understand that the stop adhesive **45** is carefully dispensed and selected, and the stop members **44** are placed in a specific manner (e.g., with a specified downward pressure) to ensure that the distance between the stop member **44** and the diaphragm **36** is a certain prescribed distance from the diaphragm **36**. Of course, this distance is subject to certain manufacturing tolerances commonly associated with conventional packaging processes.

To provide more precision in the spacing between the stop members **44** and microphone dies **20**, some embodiments may place protruding features (e.g., fillets) on the stop member **44** or the microphone die **20** to more precisely position the stop members **44**. For example, such embodiments may have downwardly protruding fillets or other protrusions from the stop member **44** that contact but do not adhesively couple with the microphone die **20**—they only make contact with the microphone die **20**. Accordingly, the stop adhesive **45** can more coarsely couple the members together while the protrusions provide the precise spacing and planar relationships.

To minimize any interference with the movement of the diaphragm **36**, this stop adhesive **45** preferably does not contact the diaphragm **36** or springs **42** of any microphone die **20**. If used in the embodiment in which the stop member **44** has a controlled voltage, then this adhesive optionally may be conductive and positioned over additional pads **21** on the top surfaces of the microphone dies **20**. After dispensing the stop adhesive **45**, this step then places the stop members **44** directly on their respective microphone dies **20** (e.g., see FIG. **6**B).

It should be noted that the stop adhesive application and stop member placement portions of this step may be omitted if the stop member **44** was formed directly on the microphone die **20** during the fabrication process.

Step **804** then secures the lids **26** to the panels by conventional means. For example, the process may apply a plurality of rings of adhesive about each base **24** on the panel. Some embodiments may use a conductive adhesive to appropriately control the potential of the lids **26**. For example, such embodiments may normally ground the potential of the lid **26** during use.

At this point, the panel may be considered to have a plurality of independently functional packaged microphones **10**. Accordingly, the process concludes at step **806**, which dices the panel along prescribed lines in the panel to form the plurality of independent packaged microphones **10**. Just prior to dicing, however, some embodiments may test the devices using conventional testing/probe processes.

Accordingly, using one or more simple stop members **44** as ruggedizing reinforcement, illustrative embodiments significantly enhance the robustness and potential usable lifespan of a microphone die **20** mounted with its backplate **34** in the front volume. Expensive flip-chip equipment is not required to protect the diaphragm **36**. In fact, regardless of its mounting within the interior chamber **28**, such a design is expected to better withstand undesired high pressure acoustic signals than those designs that do not have a stop member **44**.

Although the above discussion discloses various exemplary embodiments of the invention, it should be apparent that those skilled in the art can make various modifications that will achieve some of the advantages of the invention without departing from the true scope of the invention.

What is claimed is:

1. A microphone system comprising:

a package having an interior chamber and an inlet aperture for receiving an acoustic signal;

a single backplate microphone die having a single backplate and a diaphragm that together form a single plate variable capacitance, the single backplate microphone die being positioned to form a front volume between the diaphragm and the inlet aperture within the package interior, the single backplate microphone die being positioned to form a back volume defined in part by the diaphragm within the interior chamber;

a stop member positioned in the back volume and generally over the moveable portion of the diaphragm, the diaphragm being between the stop member and the backplate, wherein the diaphragm has a generally planar top surface, the stop member being spaced a given distance from the top surface of the diaphragm to limit orthogonal movement of the diaphragm in a direction that is generally normal to the top surface of the diaphragm, the maximum orthogonal movement being about the given distance, the diaphragm and backplate being spaced a second distance apart, the given distance being different from the second distance.

2. The microphone system as defined by claim **1** wherein the stop member is secured to the single backplate microphone die, the distance between the stop member and the diaphragm being a first distance, the distance between the backplate and diaphragm being a second distance, the first distance being different from the second distance.

3. The microphone system as defined by claim **1** wherein the package has at least one interior wall that defines the interior chamber, the stop member being coupled to the at least one interior wall.

4. The microphone system as defined by claim **1** wherein the stop member comprises a generally planar member forming at least one opening therethrough.

5. The microphone system as defined by claim **1** wherein the stop member comprises a laminate.

6. The microphone system as defined by claim **1** wherein the single backplate microphone die is positioned to substantially cover the inlet aperture.

7. The microphone system as defined by claim **1** wherein the package comprises a base forming the inlet aperture, and a lid secured to the base, the lid and base forming the interior chamber, the package further having a plurality of pads on the base.

8. The microphone system as defined by claim 1 wherein the stop member has a floating potential or has a potential that is substantially the same as the potential of the diaphragm.

9. The microphone system as defined by claim 1 wherein the stop member and single backplate microphone die are in a stacked configuration.

10. A microphone system comprising:

a base;

a lid that at least with the base forms a package having an interior chamber, the package having an inlet aperture for receiving an acoustic signal;

a single backplate microphone die within the interior chamber and having a diaphragm with a movable portion, the single backplate microphone die being mounted over and covering the inlet aperture; and

a stop member proximate to the single backplate microphone die and positioned generally over the moveable portion of the diaphragm, the single backplate microphone die being between the inlet aperture and the stop member wherein the diaphragm is movable in response to receipt of an acoustic signal, the diaphragm having a generally planar top surface, the stop member being spaced a given distance from the top surface of the diaphragm to limit orthogonal movement of the diaphragm in a direction that is generally normal to the top surface of the diaphragm, the maximum orthogonal movement being about the given distance.

11. The microphone system as defined by claim 10 wherein the stop member is secured to the single backplate microphone die.

12. The microphone system as defined by claim 10 wherein the stop member comprises a generally planar member forming at least one opening therethrough.

13. The microphone system as defined by claim 10 wherein the stop member and single backplate microphone die are in a stacked configuration.

14. The microphone system as defined by claim 10 wherein the stop member has a generally planar bottom face, the microphone having a generally planar diaphragm, the diaphragm being generally parallel with the bottom face of the stop member.

15. A microphone system comprising:

a base;

a lid that at least with the base forms a package having an interior chamber, the package having an inlet aperture for receiving an acoustic signal;

a single backplate microphone die within the interior chamber, the single backplate microphone die being mounted over and covering the inlet aperture, the single backplate microphone die having a diaphragm suspended by at least one spring, the single backplate microphone die also having a single backplate that forms a variable capacitor with the diaphragm,

the diaphragm having a generally planar top face, the spring permitting the diaphragm to move a maximum distance in a direction that is generally orthogonal to the top face of the diaphragm, the maximum distance being a distance that could damage the single backplate microphone die; and

a stop member positioned generally over the moveable portion of the diaphragm and being positioned proximate to and spaced a given distance from the diaphragm in a direction that is generally orthogonal to the top face of the diaphragm, the given distance being less than the maximum dimension, the stop member being between the diaphragm and the lid and preventing the diaphragm from moving more than the given distance.

16. The microphone system as defined by claim 15 wherein moving the diaphragm the maximum distance could damage the diaphragm, the spring, or both the spring and the diaphragm.

17. The microphone system as defined by claim 15 wherein the stop member is coupled with the single backplate microphone die.

18. The microphone system as defined by claim 15 wherein the backplate is positioned between the diaphragm and the inlet aperture.

19. The microphone system as defined by claim 1 as defined by claim 1 wherein the single backplate microphone die being mounted over and covering the inlet aperture and being positioned between the inlet aperture and the stop member.

20. The microphone system as defined by claim 10 wherein the single backplate microphone die being mounted over and covering the inlet aperture and being positioned between the inlet aperture and the stop member.

21. The microphone system as defined by claim 15 wherein the single backplate microphone die being mounted over and covering the inlet aperture and being positioned between the inlet aperture and the stop member.

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